International Research Journal of Innovations in Engineering and Technology (IRJIET)

ISSN (online): 2581-3048

Volume 8, Issue 7, pp 159-166, July-2024

https://doi.org/10.47001/IRJIET/2024.807017

From Glaciers to Grasslands: Comparative Analysis of Climate Trends in Manang and Mustang, Nepal

[1]*Pokhrel Ankita, [2]Ping Fang

[1,2]College of Environment Science and Engineering, Tongji University, China

[1,2]UNEP-Tongji University - Institute of Environment for Sustainable Development

Authors E-mail: [1]*ankita.pokhrel98@gmail.com, [2]fangping2000@tongji.edu.cn

***Abstract* - This study examines the effects of climate change on Nepal's Manang and Mustang districts by analyzing temperature and precipitation trends, changes in glacial extent, and land cover transformations. Utilizing Landsat imagery from 1992 to 2023 and historical meteorological data, we assess environmental changes in land cover. The results indicate significant decreases in precipitation, particularly during the monsoon season, alongside increases in grassland cover and reductions in barren and forested areas. Manang shows a distinct pattern with rising snowfall, whereas Mustang experiences a notable decline in rainfall, underscoring the necessity for region-specific adaptation strategies. These findings offer critical insights for shaping climate policies and developing robust strategies to enhance the resilience of high-altitude environments.**

Keywords: Climate Change, Environmental Monitoring, Remote Sensing, Himalayas, Manang, Mustang, Nepal, Adaptation Strategies, Glacial Retreat, Precipitation Trends.

I. Introduction

Climate change introduces a multifaceted array of challenges that intensify with each increment of global temperature, significantly impacting both human and ecological systems. Current projections indicate that global greenhouse gas (GHG) emissions commitments made before COP26 will not prevent warming beyond 1.5°C, further complicating efforts to limit the temperature rise to below 2°C post-2030 (IPCC, 2023).Climate change poses significant threats to the world's most fragile ecosystems, and the Himalayan region, often referred to as the "Third Pole," is no exception (Mukherji *et al.,* 2015). This region is home to the largest concentration of glaciers outside the polar areas, acting as a crucial water source for over a billion people across Asia (Immerzeel *et al.,* 2020). Understanding the impacts of climate change on the Himalayas is critical, as these changes affect not only the local environment but also the livelihoods and water security of millions of people downstream.

This study compares the impacts of climate change on the Manang and Mustang regions of Nepal by analyzing temperature and precipitation trends, changes in glacial extent, and land cover transformations. Utilizing Landsat imagery from 1992 to 2023 and historical meteorological data, we assess environmental changes and adaptive responses in these high-altitude regions. The research provides critical insights into regional climate dynamics and adaptive strategies, offering valuable information for policymakers and communities to develop effective adaptation and mitigation measures.

II. Overview of Climate Change in the Himalayas

The Himalayas are a critical indicator of climate change, experiencing temperature increases that are significantly higher than the global average, thereby reflecting the impacts of climate change more intensely than many other regions. Recent research indicates that the Himalayas are experiencing rapid climate changes, with temperature increases significantly higher than the global average. Studies have shown that higher altitudes are warming faster than lower regions, leading to a range of ecological and hydrological impacts (Pepin *et al.,* 2015). The region's glaciers are particularly sensitive to temperature changes, resulting in accelerated melting and glacial retreat (Chauhan *et al.,* 2023). Changes in precipitation patterns are also evident, with some areas experiencing more intense rainfall while others face prolonged droughts. These changes are disrupting traditional agricultural practices and increasing the risk of natural disasters such as floods and landslides (Li et al., 2018).

The impacts of climate change extend beyond physical and ecological changes, affecting the socio-economic stability of the region. Communities in the Himalayas, who depend heavily on agriculture, livestock rearing, and tourism, are particularly vulnerable. Adverse impacts on mountain resources can lead to food and water insecurity, affecting the health and livelihoods of local populations (Momblanch *et al.,* 2019).

III. Climate Change Impacts on Manang and Mustang

Manang and Mustang districts in Nepal, while sharing several commonalities, also exhibit distinct differences. Both

International Research Journal of Innovations in Engineering and Technology (IRJIET)

ISSN (online): 2581-3048

Volume 8, Issue 7, pp 159-166, July-2024

https://doi.org/10.47001/IRJIET/2024.807017

districts are remote, mountainous regions with economies driven by tourism, supported by agriculture, and animal husbandry. They have rich cultural heritages influenced by Tibetan Buddhism, and their populations include Tibetan-origin ethnic groups.

However, Manang is characterized by high mountains, valleys, and glacial lakes, with a varied climate ranging from temperate to alpine, whereas Mustang features high-altitude deserts in the north and lush valleys in the south, with a semi-arid climate. This makes Manang vulnerable to landslides and avalanches, while Mustang faces the risks of droughts and desertification. Both are prone to glacial lake outburst floods due to glacial melt. Both districts face challenges such as geographical isolation, harsh climates, and limited infrastructure, with ongoing development efforts aimed at improving connectivity, healthcare, education, and sustainable tourism. There are multiple cases of climate induced incidents recorded in Nepal's Disaster Risk Reduction Portal (DRR) both Manang and Mustang including heavy rainfall, floods and landslide taking multiple lives and millions of worth damages.

IV. Methodology

4.1 Study Area

The study area encompasses the Manang and Mustang districts in Nepal, regions characterized by their unique geographical, climatic, and socioeconomic features. These districts, located in the central part of the Nepalese Himalayas, present a compelling case for examining the differential impacts of climate change due to their distinct environmental conditions and adaptive capacities.

As illustrated in Figure 1, Manang and Mustang are situated within the Annapurna Conservation Area, one of the largest protected areas in Nepal. The map highlights the elevation gradient across these districts, ranging from approximately 412 meters to 7,733 meters above sea level, indicating significant topographical diversity.

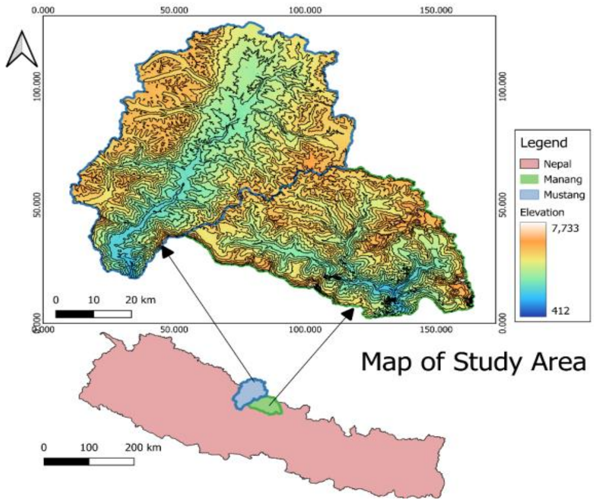

Figure 1: Map of Nepal highlighting study area with its elevation

4.2 Data Collection

Landsat Collection 2 imagery was downloaded from the USGS Earth Explorer platform for the remote sensing component of this study. This dataset (

Table 1) includes images from Landsat 5 and 8, providing a historical record of the region from the 1990s to the present. In this study, the image selection process was conducted meticulously following specific criteria to ensure the quality and reliability of the data for subsequent analysis. The temporal coverage criterion dictated that images were exclusively chosen from the post-monsoon dry season months of October and November. This selection was made to establish a consistent basis for inter-annual comparisons, as these months are relatively stable regarding environmental conditions and vegetation dynamics. The cloud cover threshold was another crucial criterion employed in the image selection. Only images with less than 5% cloud cover were considered for inclusion in the analysis. Furthermore, using Landsat Collection 2 images provided a significant advantage in terms of data quality. These images come pre-processed with atmospheric corrections, eliminating the need for additional steps to compensate for atmospheric interference. This pre-processing step ensured that the data used for analysis was free from atmospheric artifacts and ready for direct use in subsequent analytical procedures.

Table 1: Landsat Satellite Imagery Used in the Study

Date	Satellite/Sensor	Scene (Path/Row)	Cloud Coverage
1992/11/15	Landsat 5 TM	142/40	4%
2003/11/30	Landsat 5 TM	142/40	2%
2013/10/08	Landsat 8 OLI	142/40	3.52%
2023/11/05	Landsat 8 OLI	142/40	3.67%

International Research Journal of Innovations in Engineering and Technology (IRJIET)

ISSN (online): 2581-3048

Volume 8, Issue 7, pp 159-166, July-2024

https://doi.org/10.47001/IRJIET/2024.807017

Daily temperature and rainfall data from 1983 to 2023 were obtained from the Department of Hydrology and Meteorology (DHM) in Nepal from the ground stations as shown in Table 2. To represent the precipitation and temperature trends in Manang and Mustang, we selected climate stations within these districts. Out of the 10 available stations, only 5 had the necessary data for the desired years. Four of these stations were in Mustang, including two temperature stations. Unfortunately, no temperature station was available in Manang. Whereas, we used data from the Jomsom station to analyze Mustang's temperature. For precipitation, the Samar Gaun station was chosen to represent Mustang due to its similar elevation to the Manang Bhot station. The Manang Bhot station, the only available station in Manang, was used to represent Manang district.

Table 2: Selected Meteorological Stations

Station Index	Name	District	Latitude	Longitude	Elevation (m)	Type of Station
0820	Manang Bhot	Manang	28.66627	84.02257	3556	Precipitation
0624	Samar Gaun	Mustang	28.96202	83.80163	3610	Precipitation
0601	Jomsom	Mustang	28.7840111	83.7298167	2741	Temperature

4.3 Data Processing

Temperature and precipitation data were first checked for consistency and completeness. Any missing data points were addressed using linear temporal interpolation methods where appropriate. Man-Kendall and Sen-slope estimator was used to analyze the climate trend of the selected stations. Geographic Information System (GIS) tools were used to integrate and visualize various datasets. Maximum Likelihood Method was used to classify the land covers using supervised classification.

V. Results and Discussion

5.1 Climate Trends

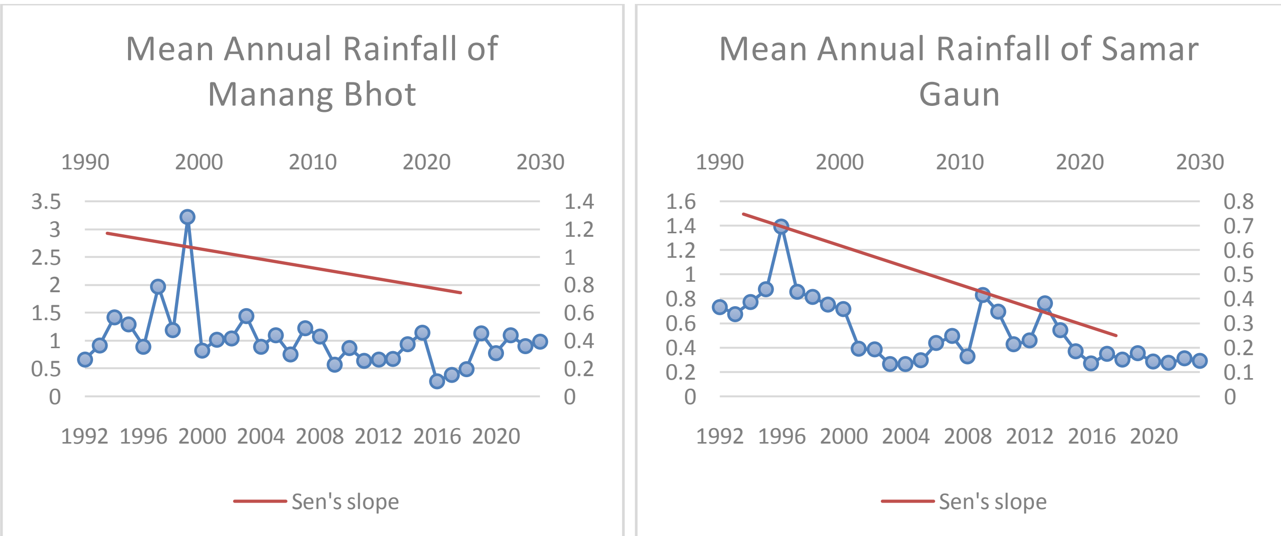

Figure 2: Precipitation trend of both stations

Figure 2 illustrates the mean annual rainfall trends for the two stations, Manang Bhot and Samar Gaun, from 1992 to 2023. The charts clearly show differing precipitation trends at these locations. The mean annual rainfall has exhibited a slight decrease over the study period. The Sen's slope, represented by the orange line, indicates a negative trend, although the p-value of 0.053 suggests this trend is not statistically significant. This aligns with the summarized annual precipitation trend analysis in Table 3, which shows no significant trend (Sen slope: -0.014). The mean annual rainfall at Samar Gaun has shown a more pronounced decrease, with a statistically significant negative trend. The Sen's slope, indicated by the orange line, highlights this decline. This finding is corroborated by Table 3, which shows a significant negative trend (Sen slope: -0.016).

International Research Journal of Innovations in Engineering and Technology (IRJIET)

ISSN (online): 2581-3048

Volume 8, Issue 7, pp 159-166, July-2024

https://doi.org/10.47001/IRJIET/2024.807017

Table 3: Summarized annual precipitation trend analysis results

Stations	Sen slope	P-value	Trend
Manang Bhot	-0.014	0.053	No Trend
Samar Gaun	-0.016	**0.000**	Negative

Table 4 provides a detailed analysis of the seasonal mean precipitation trends from 1992 to 2023 for both stations, as determined by the Mann–Kendall test. For Manang Bhot, the seasonal analysis reveals that there is no significant trend in precipitation during the winter (DJF) and spring (MAM) seasons, with Sen slopes of 0.000 and -0.010, and p-values of 0.962 and 0.214, respectively. However, a significant negative trend is observed during the summer monsoon (JJA) with a Sen slope of -0.022 and a p-value of 0.039. The autumn (SON) season shows no significant trend, with a Sen slope of -0.020 and a p-value of 0.180.

While Samar Gaun station's seasonal precipitation trends indicate no significant change during the winter (DJF) and spring (MAM) seasons, with Sen slopes of -0.001 and -0.006, and p-values of 0.936 and 0.074, respectively. In contrast, a significant negative trend is found during the summer monsoon (JJA) with a Sen slope of -0.045 and a p-value of 0.002, and during the autumn (SON) season with a Sen slope of -0.012 and a p-value of 0.007.

Table 4: Mann–Kendall test results for seasonal mean precipitation for time series (1992–2023) for Manang and Mustang

Station / Seasons	Sen slope	P-value	Trend
Manang Bhot			
DJF	0.000	0.962	No Trend
MAM	-0.010	0.214	No Trend
JJA	-0.022	**0.039**	Negative
SON	-0.020	0.180	No Trend
Samar Gaun			
DJF	-0.001	0.936	No Trend
MAM	-0.006	0.074	No Trend
JJA	-0.045	**0.002**	Negative
SON	-0.012	**0.007**	Negative

Figure 3 illustrates the trends in maximum and minimum temperatures in Jomsom over the study period. The Sen's slope values indicate a slight increase in both maximum and minimum temperatures. However, the p-values suggest that these trends are not statistically significant.

The maximum temperature shows a very slight positive trend with a Sen slope of 0.001 and a p-value of 0.866, indicating no significant change over the study period. Similarly, the minimum temperature trend also shows a slight positive increase with a Sen slope of 0.006 and a p-value of 0.745, which is also not statistically significant.

International Research Journal of Innovations in Engineering and Technology (IRJIET)
ISSN (online): 2581-3048
Volume 8, Issue 7, pp 159-166, July-2024
https://doi.org/10.47001/IRJIET/2024.807017

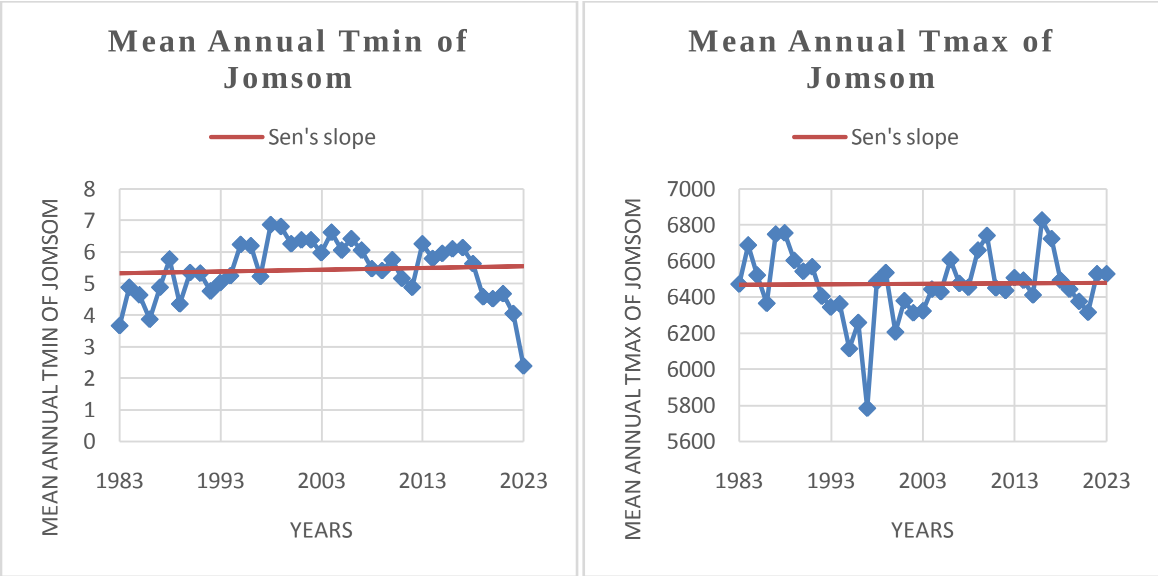

Figure 3: Minimum and maximum temperature trend of Jomsom station, Mustang

5.2 Environmental Changes

We analyzed the land cover data for the districts of Manang (2,246 km²) and Mustang (3,573 km²) over four time periods: 1992, 2003, 2013, and 2023. The data was categorized into five land cover types: Snow, Forest, Grassland, Barren, and Water. The results are presented in Figure 4 and Table 5 to illustrate the changes over time.

Table 5: Manang and Mustang land cover change for the years 1992-2023

Year	Region	Snow (km² / %)	Forest (km² / %)	Grassland (km² / %)	Barren (km² / %)	Water (km² / %)
1992	Manang	422.6463 (18.19%)	311.6358 (13.41%)	486.5058 (20.93%)	1062.0423 (47.28%)	41.1156 (1.77%)
1992	Mustang	261.0792 (7.31%)	227.4606 (6.37%)	1114.2801 (31.21%)	1956.4524 (54.80%)	11.043 (0.31%)
2003	Manang	354.9249 (15.27%)	357.9777 (15.40%)	267.5124 (11.51%)	1307.1915 (56.25%)	36.3393 (1.56%)
2003	Mustang	233.361 (6.54%)	235.1475 (6.59%)	348.5691 (9.76%)	2749.2813 (77.00%)	3.9564 (0.11%)
2013	Manang	529.3854 (22.78%)	218.7774 (9.41%)	945.0801 (40.67%)	620.0523 (26.68%)	10.6506 (0.46%)
2013	Mustang	526.698 (14.75%)	151.0515 (4.23%)	1327.9707 (37.19%)	1552.3542 (43.48%)	12.2409 (0.34%)
2023	Manang	643.4811 (27.69%)	92.9133 (4.00%)	1162.1052 (50.01%)	383.589 (16.51%)	41.8572 (1.80%)
2023	Mustang	404.8074 (11.34%)	46.6434 (1.31%)	2015.9838 (56.47%)	1050.0777 (29.41%)	52.803 (1.48%)

In 1992, the dominant land cover in Manang was barren land, covering 1,062.04 km² (47.28%), followed by grassland at 486.51 km² (20.93%), snow at 422.65 km² (18.19%), forest at 311.64 km² (13.41%), and water at 41.12 km² (1.77%).By 2003,

International Research Journal of Innovations in Engineering and Technology (IRJIET)

ISSN (online): 2581-3048

Volume 8, Issue 7, pp 159-166, July-2024

https://doi.org/10.47001/IRJIET/2024.807017

barren land had increased to 1,307.19 km² (56.25%), while grassland and snow saw decreases to 267.51 km² (11.51%) and 354.92 km² (15.27%), respectively. Forest slightly increased to 357.98 km² (15.40%), and water decreased to 36.34 km² (1.56%).

From 2003 to 2013, there was a notable increase in grassland, which expanded to 945.08 km² (40.67%). Barren land decreased significantly to 620.05 km² (26.68%), while snow increased to 529.39 km² (22.78%). Forest cover dropped to 218.78 km² (9.41%), and water further decreased to 10.65 km² (0.46%).The period from 2013 to 2023 saw grassland becoming the most dominant land cover type in Manang, increasing to 1,162.11 km² (50.01%). Snow continued to increase to 643.48 km² (27.69%), whereas barren land decreased to 383.59 km² (16.51%). Forest cover dropped sharply to 92.91 km² (4.00%), and water saw a slight increase to 41.86 km² (1.80%).

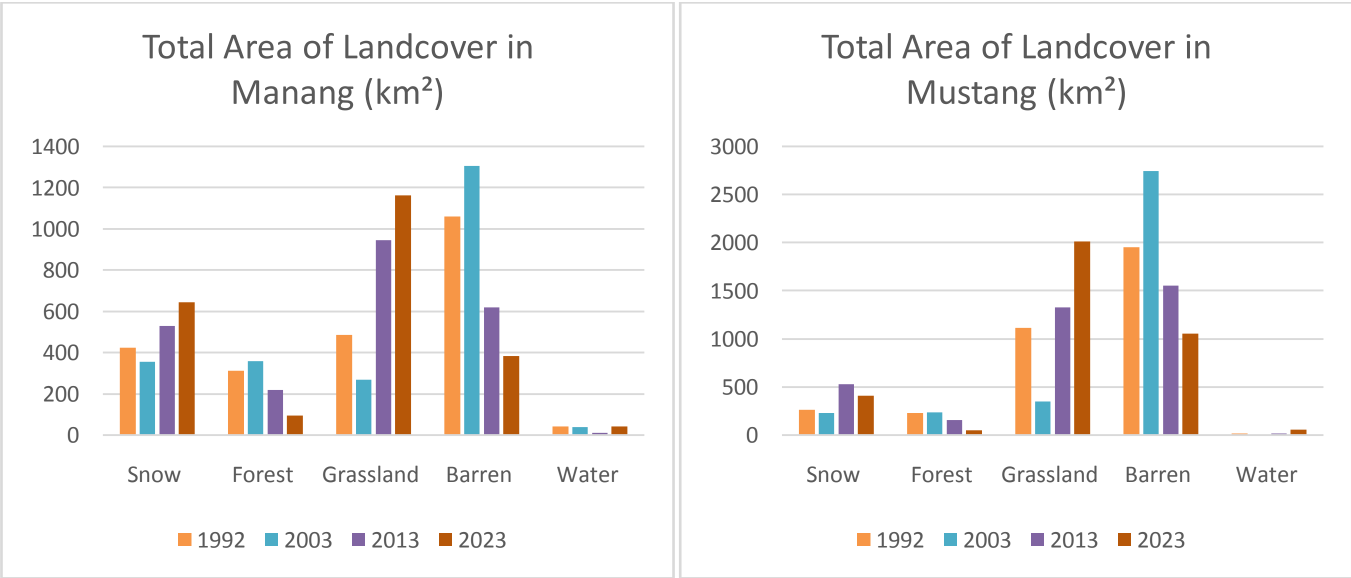

Figure 4: Total area in hectares of each land cover category at both districts

In Mustang, barren land was the predominant land cover in 1992, covering 1,956.45 km² (54.80%), followed by grassland at 1,114.28 km² (31.21%), snow at 261.08 km² (7.31%), forest at 227.46 km² (6.37%), and water at 11.04 km² (0.31%).

By 2003, barren land had significantly increased to 2,749.28 km² (77.00%), while grassland decreased to 348.57 km² (9.76%). Snow and forest decreased slightly to 233.36 km² (6.54%) and 235.15 km² (6.59%), respectively, and water reduced to 3.96 km² (0.11%).

From 2003 to 2013, Mustang saw a dramatic reduction in barren land to 1,552.35 km² (43.48%), while grassland increased to 1,327.97 km² (37.19%). Snow increased significantly to 526.70 km² (14.75%), and forest decreased to 151.05 km² (4.23%). Water increased to 12.24 km² (0.34%).

During the 2013-2023 period, grassland in Mustang surged to 2,015.98 km² (56.47%), becoming the most dominant land cover type. Barren land decreased to 1,050.08 km² (29.41%). Snow decreased to 404.81 km² (11.34%), and forest saw a significant drop to 46.64 km² (1.31%). Water increased to 52.80 km² (1.48%).

The analysis reveals that both districts experienced significant changes in their land cover over three decades.

Manang:

- Grassland area consistently increased, becoming the dominant land cover by 2023.
- Snow cover also increased over the years.
- Barren land and forest areas decreased significantly.
- Water cover showed fluctuations but remained a minor component of the land cover.

Mustang:

- Grassland became the dominant land cover type by 2023, reflecting a significant increase from 2003 onwards.
- Barren land, while initially increasing, showed a decreasing trend from 2003 to 2023.
- Snow and forest areas decreased over time.
- Water cover remained relatively stable but increased slightly towards the end of the study period.

5.3 Discussion

The analysis of climatic and environmental data from the Manang and Mustang regions reveals significant trends and

ISSN (online): 2581-3048
Volume 8, Issue 7, pp 159-166, July-2024
https://doi.org/10.47001/IRJIET/2024.807017

changes over the study period from 1992 to 2023. Both regions experienced notable decreases in precipitation, particularly during the summer monsoon season, which is critical for water supply and agriculture. The Sen's slope analysis indicated a statistically significant negative trend in annual rainfall for Samar Gaun in Mustang, while Manang Bhot in Manang showed a non-significant decreasing trend. These changes in precipitation have direct implications for water availability, agricultural productivity, and the frequency and severity of natural disasters like landslides and floods.

Land cover analysis showed a consistent increase in grassland areas in both districts, coupled with a decrease in barren and forested areas. In Manang, snow cover increased, suggesting changes in seasonal snowmelt patterns that could impact river flows and water availability. Mustang exhibited a significant increase in grassland, likely due to changes in land management practices and climate conditions. These environmental changes underscore the complex and interrelated impacts of climate change on the region's ecosystems.

The climate change impacts observed in Manang and Mustang are relevant globally, particularly for other high-altitude regions facing similar challenges. The global community must recognize and support efforts to address climate change in vulnerable regions like the Himalayas, as these areas play a crucial role in global water cycles and biodiversity. The results of this study underscore the need for robust regional climate policies that consider the unique environmental and socio-economic conditions of the Himalayas. Policymakers should prioritize investments in infrastructure that supports water management, disaster risk reduction, and sustainable agriculture.

Effective climate monitoring is crucial for understanding and addressing the impacts of climate change, particularly in sensitive and vulnerable mountain regions. However, there is a significant lack of meteorological stations in these areas, which hampers the accuracy and comprehensiveness of climate data. Increasing the number of meteorological stations and improving data collection methods in these regions will be essential for better climate modeling and adaptation strategies.

5.4 Comparison of Manang and Mustang

While both Manang and Mustang are located within the central Nepalese Himalayas and share some common climatic and geographical characteristics, they exhibit distinct differences in their responses to climate change. Manang, with its higher mountains and glacial lakes, is more prone to issues related to glacial melt and avalanches, whereas Mustang, characterized by high-altitude deserts and semi-arid climate, faces challenges related to drought and desertification.

Precipitation trends show that Mustang is experiencing a more significant decline in rainfall, which poses severe risks for its semi-arid environment. Manang, on the other hand, faces a mix of decreasing precipitation and increasing snowfall, affecting its water resources differently. These variations necessitate region-specific adaptation strategies that address the unique environmental and climatic conditions of each district.

VI. Conclusion

This study comprehensively analyzed the impacts of climate change on the Manang and Mustang regions of Nepal, focusing on temperature and precipitation trends, as well as land cover changes from 1992 to 2023. We found significant decreases in precipitation, especially during the summer monsoon, and notable shifts in land cover, with grassland areas increasing and barren and forested areas decreasing. Mustang experienced a more pronounced decline in precipitation compared to Manang, which saw significant increases in snow cover. These changes have critical implications for water resources and agricultural practices in both regions.

The findings underscore the importance of region-specific adaptation measures to address the unique environmental challenges faced by each district. Ongoing monitoring is essential to track the dynamic impacts of climate change and inform effective adaptation strategies. These insights provide a valuable foundation for developing regional climate policies aimed at enhancing the resilience of high-altitude environments.

This enhanced understanding of climate change impacts in Manang and Mustang offers critical insights for policymakers and communities, enabling them to develop robust strategies to enhance resilience and sustainability in high-altitude regions.

VII. Future Scope

Future research can enhance the current study by using higher resolution satellite data, such as Sentinel-2 and LiDAR, to capture detailed and frequent environmental changes. Incorporating advanced climate models will improve predictions of future scenarios, while implementing cloud masking techniques is suggested which will ensure more accurate satellite image analysis. Further, topographical correction of the satellite images to decrease the effects of mountainous terrain is recommended. Establishing long-term environmental monitoring programs and integrating community-based GIS (CBGIS) approaches will provide valuable time series data and incorporate local knowledge. Additionally, future studies should explore the impacts on

ISSN (online): 2581-3048
Volume 8, Issue 7, pp 159-166, July-2024
https://doi.org/10.47001/IRJIET/2024.807017

biodiversity and ecosystem services to develop comprehensive adaptation strategies. These efforts will inform regional and national climate policies, supporting targeted and effective adaptation measures for high-altitude environments.

ACKNOWLEDGEMENT

We would like to express our sincere gratitude to the Department of Hydrology and Meteorology (DHM) in Nepal for providing the essential climate data that made this research possible. We extend our thanks to the USGS Earth Explorer platform for access to Landsat satellite imagery, which was crucial for our analysis. We are grateful to our colleagues and advisors for their valuable feedback and guidance throughout the study.

REFERENCES

[1] Bhatt P, Pickering CM. Spatial and Temporal Patterns of Visitation in the Annapurna Conservation Area, Nepal: Insights From Geolocated Social Media Images. Mountain Research and Development 2022;42:16–24. https://doi.org/10/gtpp3b.

[2] Chauhan HK, Gallacher D, Bhatt A, Bisht AK. The Himalayas: A climate change laboratory. Environmental Development 2023; 45:100814. https://doi.org/10.1016/j.envdev.2023.100814.

[3] Darnal P. Mustang Where Civilization Flourished. HISAN: J Hist Ass Nep 2022;8:67–78. https://doi.org/10/gtpp34.

[4] England MI, Haines D. Topography and the Hydraulic Mission: Water Management, River Control and State Power in Nepal. International Journal of Water Resources Development 2018;37:508–30. https://doi.org/10/gtpp29.

[5] Immerzeel WW, Lutz AF, Andrade M, Bahl A, Biemans H, Bolch T, et al. Importance and vulnerability of the world's water towers. Nature 2020;577. https://doi.org/10/ggh65t.

[6] IPCC. IPCC, 2023: Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, H. Lee and J. Romero (eds.)]. IPCC, Geneva, Switzerland. First. Intergovernmental Panel on Climate Change (IPCC); 2023. https://doi.org/10.59327/IPCC/AR6-9789291691647.

[7] Konchar K, Staver B, Salick J, Chapagain A, Joshi L, Karki S, et al. Adapting in the Shadow of Annapurna: A Climate Tipping Point. Journal of Ethnobiology 2015;35. https://doi.org/10/f8pdcq.

[8] Li H, Haugen JE, Xu C-Y. Precipitation pattern in the Western Himalayas revealed by four datasets. Hydrology and Earth System Sciences 2018;22:5097–110. https://doi.org/10.5194/hess-22-5097-2018.

[9] McCarthy TJ. Notes Concerning the Jaguarundi Cat (Herpailurus Yagouaroundi) in the Caribbean Lowlands of Belize and Guatemala. Mammalia 1992. https://doi.org/10/gtpp35.

[10] Momblanch A, Papadimitriou L, Jain SK, Kulkarni A, Ojha CSP, Adeloye AJ, et al. Untangling the water-food-energy-environment nexus for global change adaptation in a complex Himalayan water resource system. Science of The Total Environment 2019; 655:35–47. https://doi.org/10.1016/j.scitotenv.2018.11.045.

[11] Mukherji A, Molden D, Nepal S, Rasul G, Wagnon P. Himalayan waters at the crossroads: issues and challenges. International Journal of Water Resources Development 2015;31:151–60. https://doi.org/10.1080/07900627.2015.1040871.

[12] Pepin N, Bradley RS, Diaz HF, Baraer M, Caceres EB, Forsythe N, et al. Elevation-dependent warming in mountain regions of the world. Nat Clim Change 2015;5:424–30. https://doi.org/10/f7c28m.

[13] Ramble C. The Navel of the Demoness 2008. https://doi.org/10/dgb3v6.

[14] Xu J, Grumbine RE, Shrestha A, Eriksson M, Yang X, Wang Y, et al. The melting Himalayas: Cascading effects of climate change on water, biodiversity, and livelihoods. Conservation Biology 2009;23:520–30. https://doi.org/10/cgbbg9.

Citation of this Article:

Pokhrel Ankita, & Ping Fang. (2024). From Glaciers to Grasslands: Comparative Analysis of Climate Trends in Manang and Mustang, Nepal. *International Research Journal of Innovations in Engineering and Technology - IRJIET*, 8(7), 159-166, Article DOI https://doi.org/10.47001/IRJIET/2024.807017

****

